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ABSTRACT

The paper reviews the effects of absence of vision on perceptual functioning and considers ways in which a modified Optacon (which translates images into tactile presentations) can help visually impaired persons acquire critical cognitive and perceptual knowledge. Background research with the Tactile Vision Substitution System, a system for converting an optical image into a tactile display, is reviewed. Modification of the standard Optacon is described, and its use in exploring three dimensional objects is noted. Supplementary uses, such as pictorial representation of illustrations and signature development, are also considered. (CL)

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A MODIFIED OPTACON: TOWARDS AN EDUCATIONAL PROGRAM

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ABSTRACT

Persons blind from birth or blinded at an early age do not develop strictly visual concepts of a three-dimensional space. This results in both developmental delays and longer term cognitive and perceptual alterations in their spatial cognition of the objects that populate space, even their personal self-representation. This research is designed to develop an educational application of the already demonstrated capacity of the human tactile sensory system to mediate three dimensional, spatial information, which, in sighted persons, is carried by the visual system. We seek to demonstrate that, with an inexpensive modification to a commercially available and widely used optical-to-tactile conversation system, Telesensory Systems' Optacon, blind children can develop a richer spatial cognition and self-representation based on heretofore unavailable visual information. The research has several specific aims: develop visual spatial concepts, to work with educators of the visually impaired, and to introduce this program into an educational setting.

In a recent discussion of the long-range feasibility of sensory substitution systems in rehabilitation (Bach-y-Rita, 1983), two key points were advanced. The first is that the most successful sensory substitution systems (Braille, sign language and the long cane) share several common factors. Among these are the absence of complex instrumentation, high reliability, and appropriate transduction of one type of sensory information into another. With these systems, the sensory system that carries the information to the brain is not overwhelmed; information processing occurs in a form and rate consistent with the brain's physiological capacities and limitation. Each of the three sensory substitution systems also has limitations. In particular, each is capable of transmitting to the brain only a limited range of environmental information. Braille readers, for example, can read only limited literature. Long cane users cannot perceive overhangs nor can they gather information about the space in front of the cane tip. As a consequence of being deprived of sensory information, and therefore, being unable to perceptually experience some aspects of their world, a blind child is at a significant developmental disadvantage. Some basic visiospatial knowledge was simply beyond their experience or understanding. Consider, for example, the following passage from Lowenfeld (1955) on some of the perceptual difficulties facing the blind:

> "The sun, the moon, the clouds, the horizon, the sky are inaccessible and can be explained to blind people only by the use of analogies from other

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> sensory fields. This method must also be used in explaining to blind people such visual phenomena as shadows, perspective, and reflection of light. Many objects are too large to be observed by touch; for instance, a mountain or a large building. Other objects are too small and cannot be observed by touch with any degree of accuracy; for instance, flies or ants."

Self-representation is an especially important cognitive acquisition because it has many other ramifications for the representation of objects in the environment. Self-as-object, for example, is important because it is "the leading edge of a number of other aspects of self-identification," such as the usage of 'I' in language and play.

For the sighted, vision contributes a disproportionate amount of information useful in motor control, spatial cognition and the construction of self-image. This information is normally beyond the processing characteristics of the haptic or auditory modalities. The blind child's delay in the acquisition of 'I'-as-a-concept, for example, can be related to the problems of constructing a self-image in the absence of vision.

> "The blind child has no sensory mode available to him which will replicate his own body or body parts. The blind child is obliged to constitute a body image from the components of non-visual experience available to him...but these sensory modes bind him to egocentric body and self-experience and cannot lead him easily to the concept of self in which the self can be taken as an object, the indispensable condition of 'I'. (Fraiberg & Adelson, 1976:145)

It is our contention that the problem of such children is not the absence of sight, but rather an absence of a means by which visual information can be perceived. The modified Optacon, we argue, is capable of providing visual information through the skin; it produces a perceptual system that Fraiberg and Adelson (1976) felt could not be duplicated without vision. It does simulate vision in a number of important ways: representing particular objects in their entirety, extending out beyond the reach of the observer, and reducing the need for gross tactual exploration.

While not capable of processing information as simultaneously as the visual system, the tactile presentations through the Optacon offers numerous advantages over strictly haptic or kinesthetic presentations. The latter require the synthesis of sequentially processed information which places a heavy load on memory and other cognitive processes (e.g., a face haptically explored cannot result in the immediate representation of a face: perhaps the outline is perceived first, then the hair length, then the nose, etc. Each part must be perceived, then remembered and then synthesized into a representation of a face, or with more difficulty, into one particular face). Not only is this a considerably demanding task, but it is also limited, even with practice. The Modified Optacon can relieve the user of some of this cognitive burden: certain objects can be presented in toto (even if not in great detail), and without the necessity of sequential touching, or even touching at all.

The kinds of experiences discussed in the beginning are precisely those that have already been provided blind subjects in the earlier TVSS research (see Bach-y-Rita, 1972; 1980 for details). The provision of visual information via a different sensory modality offers the opportunity for the young blind subject to develop those cognitive concepts vital for

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spatial cognition, perceptual-motor skills, self-representation, and self-image. To reiterate, it is by no means clear that only sight can offer useful visual information. In fact, our research with the modified Optacon suggests that some quasivisual information can be made available and that certain entirely novel experiences (such as the tactile image of a flickering flame) can be perceived. It remains to be seen, of course, whether the perceptual experiences offered by the modified Optacon can have identifiable long-term developmental benefits. The modified Optacon, we propose, can provide or supplement the blind child's experience, useful in the development of self-representation in various ways: as a detached observer (rather than just an active manipulator) of objects in space, as a continuous physical entity (that is, as a complete object in space), and as an actor. Further, the proposed Optacon program offers the opportunity for the child to view him/herself as others do, so that he/she may be provided a means to reduce the anxiety associated with physical appearance.

Basic research on the means by which the visually impaired code vibrotactile information about shape, distance, location, orientation, etc. is also necessary in this endeavor because there remains considerable confusion in the literature as to the relative performance of the sighted and blind in spatial tasks. Is vision a necessary or a sufficient, or merely facilitating aspect of spatial performance? How does the memory of objects only touched compare with that for objects only seen? To what extent are differences in sighted and blind performance attributable to the amount or the type of information provided by vision and touch?

Evidence for poorer (or even different) performance by the blind on certain spatial tasks is usually interpreted as evidence for the necessity of vision in such cognitive-conceptual development, and for the separateness of the different sensory systems. The absence of visual information severely limits the subjects' knowledge of external (tactually unperceivable) relations among objects: "the congenitally totally blind lack important aspects of information, and forms of organizing it that are easily derived from vision" (Millar, 1981:310). The modified Optacon offers one means by which this scope and type of spatial information can be made available to the blind, and deprived spatial representations assessed.

Backround Research

Studies with Tactile Vision Substitution System (TVSS), which form the background for the present proposal, emerged from concepts of brain plasticity and the potential for one sensory system to substitute for another (e.g., Bach-y-Rita, 1972). The TVSS is a system for converting an optical image into a tactile display. After surprisingly little training, subjects are able to recognize common objects and to describe their arrangement in three-dimensional space. By control of the sensing and imaging device, a television camera, subjects quickly made distal attributions (i.e., understood patterns as belonging to objects localized out in space, and not just against the skin).

In order to deliver the image picked by a TV camera (under the control of the blind person) to the skin of the trunk, each point stimulated on the skin represented one small area of the image captured by the camera (much as a newspaper photograph represents a scene by an array of dots). A functional 400-point system (20 x 20 matrix in contact with a 10-inch square of skin) was completed in 1968 (Collins, 1970). More than 80 blind persons were trained or tested, of whom, 30 received more than 40 hours of training.

Learning the techniques of camera manipulation usually occupied the major portion of the first few hours

of training. This included controlling the zoom lens operation, aperture and focus, as well as directing the camera to some part of the surround. With this self-induced camera movement, subjects used the camera as part of a perceptual organ.

The visual analysis techniques and concepts thus developed were used in letter recognition, the perception of moving stimuli, and the exploration of other persons standing before a camera and the exploration of the subject himself in a mirror. Our subjects learned to discriminate between individuals, to determine where they were in the room, and to describe their posture, movements, and individual characteristics. However, detail, such as found in a photograph of a face, was particularly difficult to perceive.

We developed several portable models of the TVSS which use an array of mechanical or electrical stimulators applied to the skin of the abdomen. Subjects wore a small TV camera mounted on the frame of a pair of glasses, and a vest containing the electronics and batteries. Field testing of the TVSS for a limited industrial task was also conducted in collaboration with an electronics company. A blind technician was trained in the assembly of solid-state diodes, a high-volume task normally performed by sighted employees. After three months, he was able to perform the assembly line microassembly and inspection tasks with comparable speed and accuracy as sighted persons.

The Modified Optacon

The standard Optacon consists of a matrix of photocells and a corresponding matrix of skin stimulators. The blind person passes the matrix of photocells across the lines of print on a page and receives the output on a stimulus array of 144 (24 x 6) piezo-electric driven vibrating tips on the fingertip (Linvill and Bliss, 1971). The modifications we have applied to it are quite simple: following the deactivation of the camera's internal light source, we have fitted, above the reading aperture, an adjustable telescopic tube and inexpensive biconvex lenses of varying diameter and focal length (ranging from 11mm x 20mm x 20mm x 35mm). Figure 1 illustrates this arrangement.

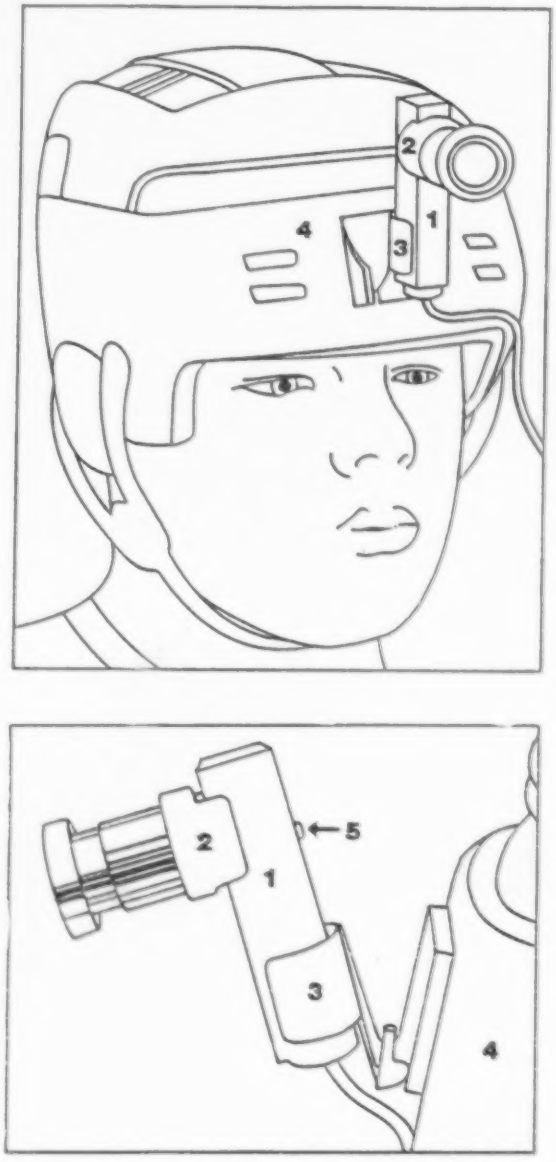

Figure 1. The standard optacon (1) modified by fitting an adjustable lens attachment (2) and angle-adjustable clasp (3) to a lightweight headpiece. Zoom adjustment is (5).

In order to provide maximal mobility in the scanning of the camera, we have permitted it to be hand held, to be mounted on an adjustable tripod, or to be mounted on a light-weight helmet or cap where it can be moved via head movements. Our primary objective in the earliest pilot work with four early-blind students (ranging in age from 13 to 28) has been to replicate as many of the effects documented in the TVSS research as possible and to develop a systematic teaching program based on this work. The learning results found so far have been positive: one of the subjects, who owns his own Optacon, learned, with eight hours of practice, to accurately identify the three-dimensional shape of a rotating wire mobile, to state its direction of rotation, and to use other monocular cues to depth perception. The other subjects who had minimal previous experience with the Optacon, progressed to the same level, but at a slightly slower rate.

The training program, as it now stands, is based on the earlier TVSS approach. What follows is a brief outline of the basic task domains on which we have based the program.

Perceptual-Motor Interactions

The modified arrangement makes substantial use of active movement on the part of the user. However, while standard operation of the Optacon is limited to linear scanning along a printed line, use of the modified Optacon requires far more varied motor involvement in different directions, over different extents, and often in an exploratory non-predictive way. learning to scan in two dimensions, learning to stabilize images, learning to reliably and accurately distinguish movement of objects in the perceptual field from movements of self is needed.

Distal attribution, a term signifying the user's ability to attribute the (changes in) stimulation at the finger tip to (changes in) distal objects located in the functional perceptual field, is constantly encouraged with verbal reminders and haptic confirmation. Accurate scanning of the perceptual field, with emphasis on the zoom and threshold manipulations, is also vital, given the narrowness of that field. Novices may also require explanation of why, with movement to the right (e.g.), the image moves to the left, and an opportunity to become familiar with this.

Much of this aspect of the curriculum parallels that is used in the standard Optacon approach, except that we use more variety in line length, width and orientation, and require that users continually make comparative perceptual and memorial judgments in practically every exercise. In scanning lines we emphasize image stability. We also include active movements by the user to correct body position, to rectify the line orientation, (e.g., if a line is supposed to be vertical but is not displayed as such on the monitor, it must be because the subject's head is tilted). This can also be used to demonstrate how a line will change its apparent orientation with a purposeful head tilt, and again, how a change in object orientation can be distinguished from head orientation. We use both straight and curved lines. This work eventually leads to the ability to distinguish the perceptual effects of self-movement from those of object movement.

The same objectives are apparent with more than one line present in the visual field: that is, we seek to have the user scan accurately, distinguish and correct for line orientations, as well as make comparisons between the geometric characteristics of the lines. For example, we ask questions regarding relative straightness of the lines, relative lengths, widths, and orientation; whether or not the lines are parallel; whether they connect, and/or intersect and, if so, at what approximate angle; and whether they form familiar patterns or alphanumeric characters. The

ability of the users to comprehend such terms is relevant, but it should also be recognized that such exercises may provide valuable practice with such terminology by a means which is perhaps more useful than the normal verbal descriptions and haptic exploration.

The gradual introduction of more complicated patterns can continue with the presentation of two-dimensional shapes. These can take the form of alphanumeric characters that may already have been learned by Optacon reading, and of other symbolic images.

Three Dimensional Objects

Learning monocular cues to size and depth is the most time consuming exercise of all, but could offer the most long-term benefits. Depth perception, after all, is one of psychology's and art's classic problems; even the sighted are faced with this problem because the very nature of the visual system involves a three-dimensional world translated onto a two-dimensional retinal surface. An understanding of how we perceive an object as being a certain constant size even though it may be moving toward or away from us, or of how we see a set of objects arranged in depth, requires an understanding not so much of the visual system but of the kinds of information, 'cues' to depth we learn to use. We define a depth cue as a pattern of proximal stimulation (in this case, the vibrotactile pattern from the Optacon) that contains information about the (three-dimensional) spatial locations of distal objects.

The following topics constitute our work in this area:

(1) Interposition: how one object can occlude, or partially occlude, another when both are in the projected line of 'sight' of the Optacon.
(2) Linear perspective: how, for example, parallel lines appear to converge as they recede in depth.
(3) Relative size: how an object, which maintains its true size, subtends a greater visual angle and hence appears larger as it approaches the 'viewer'.
(4) Motion parallax: how self-movement changes one's perspective of objects or object relationships.
(5) Effects of object motion: how objects undergo changes in perspective as they move (e.g., rotate).

Supplementary Uses

In addition to offering a means by which visuo-spatial information can be presented to blind users, our hope is that other educational benefits may be derivable from use of the motified Optacon. The following is a partial list of some possibilities we have already attempted:

(1) Pictorial Representation of Illustrations: Much of what is presented in print is supplemented with pictures, photographs or drawings. If the material is considered essential from an educational perspective, it must be converted to a tactual format (i.e., geometric figures, maps, etc.). This requires considerable hours of additional effort. If, however, a simplified representation of the picture could be viewed with the modified Optacon, much of this time and effort could be saved. The information would be elemental, but still convey the main idea in a succinct, time saving manner.

(2) Large-Scale Information: Here the need is to present scaled room, building, and travel route information in a manner that is efficient to both the modified Optacon user and the information provider.

(3) Daily Living Skills: Here

the emphasis would be on specific skills: The information provided would allow the user to either better replicate a function, understand an action or layout, or perceive the whole of a subject being discussed.

(4) Signature Development: The opportunity to observe and compare one's own handwriting is important. For the user to produce his/her signature and then contrast it, would be a significant advancement. With the modified Optacon, performance feedback can be immediate and the user's improvement can be self-monitored.

(5) Motion: The concept of movement is a difficult one to grasp. The modified Optacon provides an opportunity for the user to perceive motion without interfering with it. This is in itself a significant opportunity. That it could be applied to the live illustration of, for example, laws of physics for academic purposes, would be of real value.

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